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SCAB SUSCEPTIBILITY AND INJURY OF POTATO TUBERS BY 2, 4, 5-TRICHLOROPHENOXYACETATES[1]

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(Accepted for publication April 30, 1951)

A report indicates (2) that spraying potato foliage with the butyl ester of 2,4,5-trichlorophenoxyacetic acid increased the incidence of a scab-like type of injury on tubers. Since scab infection is intimately associated with tuber growth, this research is of particular interest to others working on the scab disease. Although the problem was not pursued further, it was suggested that plant breeders and geneticists might possibly use this growth regulator to insure a rigorous test for susceptibility or resistance of new lines to potato scab. For such a use, it is important that the fundamental processes involved in resistance, whether physiological or morphological in nature, remain unchanged following chemical treatment.

To investigate the problem further, greenhouse and field trials were made

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[2] Assistant professors of the Department of Botany and Plant Pathology.

at this station with 2,4,5-T on scab-resistant and susceptible varieties. Observations were made on scab incidence and scab lesion type.

One greenhouse trial was conducted in which three resistant and three susceptible potato varieties were grown in 6-inch pots of steam-sterilized, quartz sand under controlled nutrient conditions. Sand was infested with inoculum consisting of spores and aerial mycelium of a pure culture, of *Streptomyces scabies* grown on agar. This isolate causes severe, deep scab on Cobbler and other susceptible varieties and shallow lesions on resistant varieties (1). Plants were sprayed when the first tubers were approximately ½" in diameter with 20 ml. of the potassium salt of 2,4,5-trichlorophenoxy-acetic acid at a concentration of 800 p. p. m. A wetting agent, 0.01 per cent Tergitol 7, was used. Treatments for each variety included scab inoculum alone, 2,4,5-T alone, both scab inoculum and chemical, and a control which was neither inoculated nor sprayed with chemical. No vine necrosis or defoliation was noted at the concentrations of 2,4,5-T used in these tests although a slight curvature of petioles did occur. Tubers of plants sprayed with 2,4,5-T whether exposed to inoculum or not were often necrotic and severely eroded. Affected tissue appeared to be blistered later forming erumpent, crater-like lesions, or when a large area was involved, affected tissue was cracked and fissured. Such tissues were often slightly sunken and light tan in color. Red color was lacking in affected tissue of the red variety tested. When injury was severe, necrotic areas were sunken and deeply pitted. Adventitious roots developed in severely affected areas, generally originating at or near the eyes.

In this discussion, the term scab refers to a lesion typical of this particular scab isolate, on a specific variety. These lesions have recently been described and illustrated on most of the varieties used in these tests (1). Scab incidence on tubers was low in infested sand. However, lesions were indicative of the inherent resistance of the respective varieties. Lesions on Cobbler, Red Warba, and Katahdin were deep, whereas those on Ontario, Menominee, and 116-13 were shallow and well corked underneath.

Pitting or erosion of tubers of chemically treated plants was very similar either when exposed to *Streptomyces scabies* inoculum or when grown in the absence of the scab organism. Scab-resistant varieties were as severely affected as were susceptible varieties, suggesting either that the inherent resistance had been destroyed by treatment or that the type of injury was distinct from that of typical scab infection.

Field trials were made in 1950 in peat land in northern Iowa where potato scab is severe. This test involved four very susceptible varieties, five highly resistant ones, and one of moderate resistance to scab. The isopropyl ester of 2,4,5-trichlorophenoxyacetic acid, 2000 p. p. m., 50 gal./A., was applied on July 11 and on August 23 to one plot, on August

TABLE 1.—*Scab incidence, 2,4,5-T tuber injury, and yield of potato varieties grown in peat soil at Clear Lake, Iowa, 1950.*

Variety	Scab Type	No Spray: Scab Incidence[1]		No Spray: Yield[3]	One Spray: Scab Incidence[1]		One Spray: Chemical Injury[2]		One Spray: Yield[3]	Two Sprays: Scab Incidence[1]		Two Sprays: Chemical Injury[2]		Two Sprays: Yield[3]	
		Healthy Per cent	Severe Per cent	Lbs.	Healthy Per cent	Severe Per cent	Healthy Per cent	Severe Per cent	Lbs.	Healthy Per cent	Severe Per cent	Healthy Per cent	Severe Per cent	Lbs.	Reduction Per cent
Cobbler	3+	12	55	23	26	32	100	0	20	18	49	55	22	16	30
Red Warba	3+	4	59	28	29	38	100	0	23	36	22	45	28	16	43
Katahdin	3+	2	75	28	11	44	98	1	26	34	37	40	31	17	39
Triumph	3+	9	55	19	16	40	100	0	18	20	32	63	22	7	63
Sebago	2	5	41	30	10	37	100	0	21	31	34	2	76	4	87
Ontario	1	39	11	40	55	8	100	0	22	53	14	45	38	14	65
Menominee	1	16	26	15	38	3	100	0	9	26	30	44	18	4	73
Yampa	1	24	26	31	40	11	89	11	24	27	18	31	51	10	68
Cayuga	1	33	24	3	40	20	100	0	3	67	18	37	11	1	67
116-13	1	52	8	23	45	10	100	0	19	20	29	35	51	8	65

[1] Percentage of tubers showing no scab infection, classed as healthy; and those showing over 5 per cent of the surface scabbed, classed as severe. The percentage of tubers in the intermediate group may be obtained by subtracting the sum of the healthy and severe from 100.
[2] Percentage of tubers showing no injury classed as healthy; and those showing more than 25 per cent of surface injured classed as severe.
[3] Yield in pounds from row 16 ft. long.

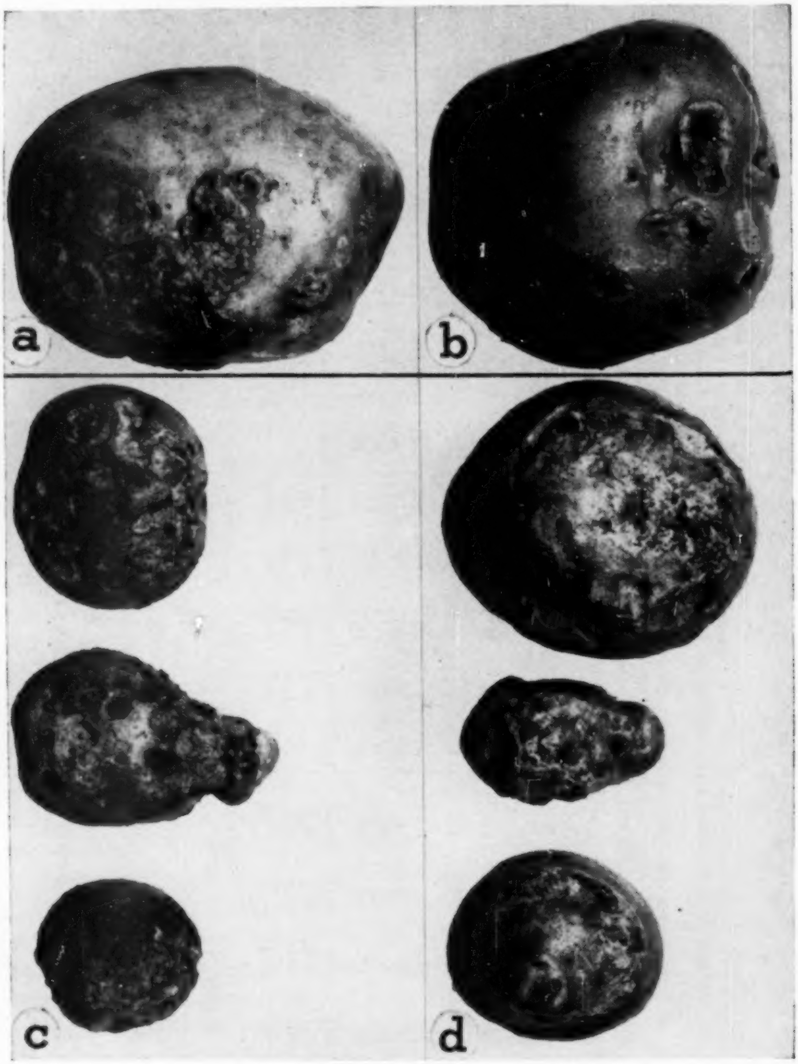

Figure 1.—Typical scab lesions following natural field infection on scab susceptible varieties, a, Cobbler and b, Red Warba. Representative tuber injury on c, Cobbler and d, Red Warba following spraying of the vines with isopropyl 2,4,5-trichlorophenoxyacetate in July and August.

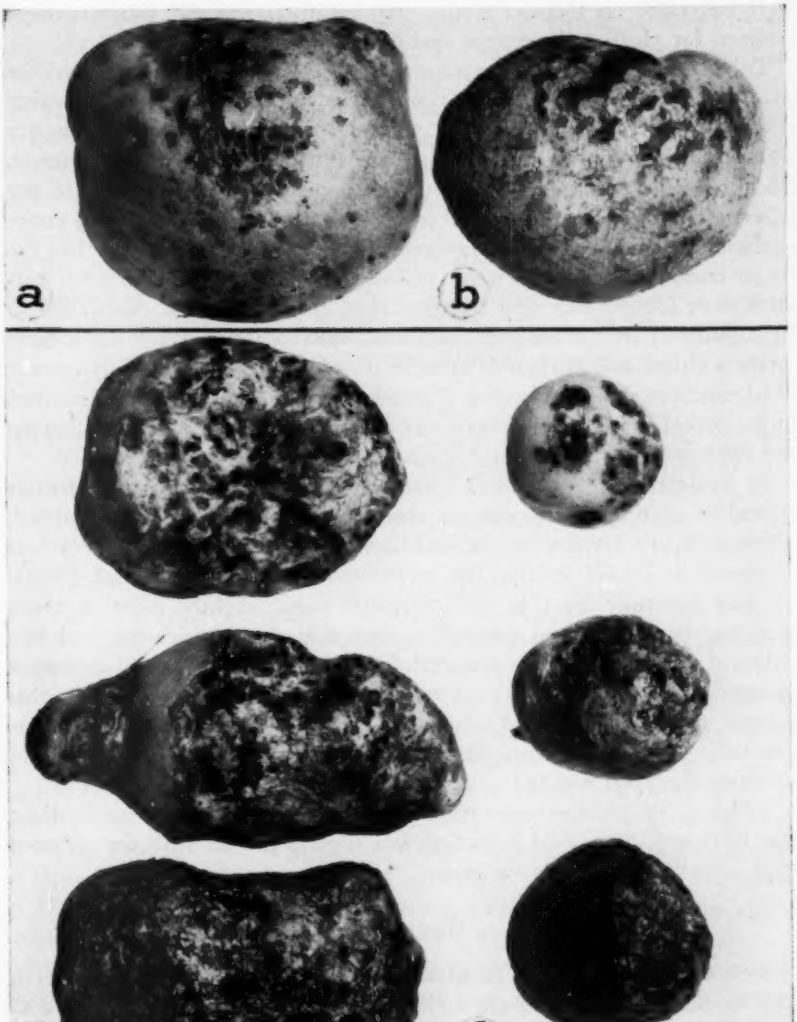

Figure 2.—Typical scab lesions following natural field infection on scab resistant varieties, a, Ontario and, b, Menominee. Representative tuber injury on, c, Ontario, and, D, Menominee following spraying of the vines with isopropyl 2,4,5-trichlorophenoxyacetate in July and August.

23 to a second plot, and an untreated control was maintained. All plots were harvested on October 9 and only potatoes over ¾" diameter were retained for yield, scab records, and other evaluations (Table 1).

Tuber damage was readily apparent in all varieties that had received the two applications of 2,4,5-T. It consisted of a severe necrosis involving relatively large areas of the tuber, figures 1 and 2. In this respect injury was somewhat distinct from scab lesions which are normally discrete. Such eroded areas generally involved the entire apical portion of the tuber, often extending downward over more than 25 per cent of the entire surface. The smaller tubers were generally more severely eroded than the larger ones. Some potatoes were girdled, suggesting that normal tuber surfaces were formed following recovery from chemical injury. Apical tips of such girdled tubers were often somewhat bulbous. This injury was similar on the resistant and susceptible varieties tested. There was some development of adventitious roots originating at or near the eyes, similar to that described in the greenhouse studies. There was practically no tuber injury following one application of 2,4,5-T in August.

In evaluating the chemical treatments, tubers with discrete lesions typical of scab on the unsprayed checks were considered to be scabbed, whereas injury atypical of the scab developing on untreated tubers was attributed to 2,4,5-T injury. The percentage of tubers free of scab (Table 1) was generally least in the untreated plots, slightly more in those receiving one spray, and generally greatest in those which received two chemical sprays, suggesting that scab infection had actually been decreased by applications of 2,4,5-T. Progeny 116-13, was the chief exception to this general trend. The amount of severe scab on susceptible varieties was generally decreased by spraying with 2,4,5-T, whereas with the resistant varieties the trend was not so apparent.

Yields of all varieties were reduced as the number of spray applications was increased. This yield reduction was slightly greater with the resistant than with the susceptible varieties.

Discussion

This experimental work confirms the observation of Wood and Ennis (2) in that injury of tubers following treatment of potato vines with 2,4,5-trichlorophenoxyacetates consisted of severe erosion and pitting. However, in the experiments herein reported, chemical injury was distinguishable from that caused by *Streptomyces scabies*. When scab inoculum was present, injury was prevalent in both field and greenhouse tests on all varieties regardless of inherent resistance to scab. In sterile sand, in the absence of the scab pathogen, tuber injury developed regardless of variety. In the field, in the presence of an abundance of *S. scabies* inoculum,

treatment with 2,4,5-T generally decreased the amount of typical scab on varieties under test. In most cases the number of severely scabbed tubers was less and the number of scab-free tubers was greater in plots receiving two applications of the chemical than in the plots sprayed only once or not at all. 2,4,5-T tuber injury was similar on all varieties.

Increases in scab incidence in a manner which would be suitable for progeny evaluation in a potato breeding program were not observed following the spraying of vines with 2,4,5-trichlorophenoxyacetates.

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NEMATODES FOUND IN NEW YORK STATE FIELDS WITH SEVERAL DIFFERENT CROPPING HISTORIES

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Many growers find continuous potato cropping convenient and profitable enough so that they are willing to run the increased risk of disease loss which the practice entails. This survey was made to determine what effect several known instances of continuous potato growing had produced on populations of pathogenic, or possibly pathogenic nematodes.

The kinds and numbers of nematodes were studied in three fields in which potatoes had been grown continuously for many years, in one field in which potatoes had been grown every other year for ten years, and in three fields in which potatoes had never been grown. Two of the fields in which potatoes had never been grown were adjacent to a field in which potatoes had been planted continuously for twenty years or more.

Fields were sampled May 10, 1950, shortly after plowing time. Shovelsful of approximately the top six inches of soil were taken at scattered locations over the fields until a bushel of soil had been obtained from each field.

The plant parasitic nematodes present in these soil samples could be of two sorts, external feeders, or internal parasites. The internal potato parasites were discovered by growing potatoes in the soil samples. To find the external feeders it was necessary to recover nematodes directly from the soil. This was done by screening 250 cc. samples of the soil obtained from each field using screens with 25, 100, and 200 meshes per

inch. The screening-gravity method of Cobb (1918) was used instead of the Baermann (1917) extraction because it was found that only a small percentage of the more sluggish nematodes (which include most of the plant parasitic species) could be obtained by the Baermann method. This fact was observed when both methods were used with some of the survey samples. It was verified by adding 5000 golden nematode (*Heterodera rostochiensis* Wollenweber) larvae to soil containing no nematodes and then recovering the nemas by screening and by the Baermann method. Approximately three per cent of the golden nematode larvae were recovered by Baermann extraction and thirty-seven per cent by screening as shown in table 1. Percentage recovery would be higher by Baermann extraction if smaller soil samples were used, and would be higher by screening if finer screens were employed.

TABLE 1.—*Percentage recovery of 5000 golden nematode larvae from 250 cc. of soil.*

	Screening—Gravity Method	Four-day (Baermann extraction)
1.	25	3
2.	42	4
3.	40	4
4.	40	2

It was not possible to determine and count all the nematodes screened from the samples. An aliquoting procedure was used. The contents of the 25, 100, and 200 mesh screens were washed into a beaker, the nematodes allowed to settle, and the water decanted to the 200 milliliter level. The 200 milliliters were stirred with an electric stirrer and a ten milliliter aliquot was taken. To check variation in nematode recovery with different levels of nematode infestation, golden nematode larvae were added to soil containing no nematodes at the rate of 100, 500, and 5000 per 250 cc. Numbers present were then determined using the screening and aliquoting procedure just described. The coefficient of variability for number of nematodes recovered was highest when the soil contained only one hundred golden nematode larvae, lower when five hundred or five thousand larvae were present per 250 cc. of soil. When the aliquot counts were multiplied by twenty, a thirty-five to fifty per cent recovery was indicated. Judging from the data in table 2, a nematode species would be found by this screening and aliquoting procedure if it were present in the soil in as low a concentration as one hundred nematodes per 250 cc. of soil.

TABLE 2.—*Recovery of golden nematode larvae by screening and aliquoting.*

Nemas Added per 250 cc. Soil	Nemas Recovered*	Nemas per Aliquot*
100	50	2.5 ± 1.1
500	200	10 ± 2
5000	1760	88 ± 25

*—mean of 6 replicates

The nematodes found in the fields together with the soil types and cropping histories are listed in table 3. Known parasites of higher plants are designated by "P", nematodes not known to be parasitic on higher plants by "N", and nematodes whose status in this regard is uncertain by "D". No golden nematodes were found in any of the fields sampled.

TABLE 3.—*Nematodes found in New York State fields with different cropping histories.*

1. Sassafras silt loam. wooded for over thirty years.

Rhabditis sp.	N
Cervidellus sp.	N
Tylenchus sp.	D
Criconemoides rusticum	P
Pratylenchus sp. 2	P
Aphelenchus avenae	D
Aphelenchoides parietinus	D
Plectus sp. 1	N
Plectus sp. 2	N
Wilsonema sp.	N
Prismatolaimus sp.	N
Dorylaimus sp. 1	N
Dorylaimus sp. 2	N
Dorylaimus obscurus	N
Xiphinema americanum	P
Diphtherophera sp.	D

2. Sassafras silt loam, in potatoes for over twenty years.

Rhabditis sp.	N
Eucephalobus sp	N
Tylenchus sp.	D
Pratylenchus sp. 2	P
Aphelenchoides parietinus	D
Dorylaimus sp.	N

3. Sassafras silt loam, wooded to 1949, cleared and planted to broccoli followed by Brussels sprouts in 1949.

Rhabditis sp.	N
Eucephalobus sp.	N
Ditylenchus sp.	P
Aphelenchoides parietinus	D

TABLE 3.—*Continued*

4. Sassafras fine sandy loam, in potatoes for over thirty-five years.

Rhabditis sp.	N
Diploscapter sp.	N
Acrobeloides sp.	N
Tylenchus sp.	D
Pratylenchus sp. 2	P
Aphelenchoides tenuicaudatus	D
Aphelenchoides parietinus	D

5. Sassafras fine sandy loam, in lima beans for over thirty years.

Rhabditis sp.	N
Acrobeles sp.	N
Acrobeloides sp.	N
Tylenchorhynchus sp.	D
Pratylenchus sp. 1	P
Paratylenchus sp.	P
Aphelenchus avenae	D
Aphelenchoides parietinus	D
Dorylaimus sp.	N

6. Lordstown silt loam, in potatoes for ten years or more.

Rhabditis sp.	N
Diploscapter sp.	N
Stegellata sp.	N
Acrobeloides sp. 1	N
Acrobeloides sp. 2	N
Eucephalobus sp.	N
Cephalobus sp.	N
Tylenchus sp.	D
Pratylenchus sp. 2	P
Criconemoides sp.	P
Aphelenchoides parietinus	D
Dorylaimus sp.	N
Dorylaimellus sp.	N

7. Ontario silt loam, alternately in potatoes and oats for ten years.

Cephalobus sp.	N
Tylenchus sp.	D
Pratylenchus sp. 2	P
Criconemoides sp.	P
Paratylenchus sp.	P
Aphelenchus avenae	D
Aphelenchoides parietinus	D
Plectus sp.	N
Dorylaimus obscurus	N

The first three fields listed were adjacent to one another. In the woods, where there was the widest variety of host plants and most organic matter, there was also the widest variety of nematodes. In the two adjoining cleared fields many species had dropped out. The only plant parasitic nematodes present in large quantity in any of the fields surveyed were two species of *Pratylenchus* which appear to be undescribed, and a *Tylenchorynchus* species in the bean field. Little work has been done with

Tylenchorhynchus and its economic importance is uncertain. *Pratylenchus* species, commonly referred to as "root lesion or meadow nematodes" are widely distributed over the world and are now suspected to be important plant pathogens. Counts of the *Pratylenchus* per 250 cc. of soil were made in the various fields in the spring, and later, after potatoes had grown in the soil for 11 weeks. (Table 4).

TABLE 4.—*Numbers of Pratylenches found in New York State fields with different cropping histories.*

	Pratylenchus per 250 cc. Soil	
	Before Potatoes	After 11 Weeks in Potatoes
1. Sassafras silt loam wooded for over 30 years	320	390
2. Sassafras silt loam in potatoes for over 20 years	156	150
3. Sassafras silt loam cleared in 1949	0	0
4. Sassafras fine sandy loam in potatoes for over 35 years	503	490
5. Sassafras fine sandy loam in lima beans for over 30 years	0	260
6. Lordstown silt loam in potatoes for 10 years or more	120	920
7. Ontario silt loam alternately in potatoes and oats for 10 years	0	100

Since only about thirty-five per cent of the nematodes were recovered by the screening, the counts in table 4 should be multiplied by three to give a truer idea of the number of *Pratylenchus* actually present in 250 cc. of each of the soils. The *Pratylenchus* which had lived in a bean field increased markedly on potatoes. No *Pratylenchus* was recovered in cleared field 3, adjacent to wooded field 1, which had a considerable *Pratylenchus* population. Possibly the broccoli and Brussels sprouts grown in 1949 in the cleared field were not hosts of this *Pratylenchus.*

Pratylenches counts were made in potato root systems grown in ten-inch pots of soil from the various fields (Table 5). Soil was removed from the roots by hand and the root systems were stained with lactophenol containing acid fuchsin. Each root system was cut up in lactophenol, the lactophenol root mixture stirred, and an aliquot taken in which the *Pratylenchus* was counted.

All counts in table 5 are probably lower than they would be if the plants had been grown in the field, unrestricted by pots, and if their roots had been washed free from soil and every rootlet included in the exam-

TABLE 5.—*Numbers of Pratylenchus found in potato root systems grown in soil from New York State fields with different cropping histories.*

	Pratylenchus per Root System (mean of 6 replicates)
1. Sassafras silt loam wooded for over 30 years	650
2. Sassafras silt loam in potatoes for over 20 years	308
3. Sassafras silt loam cleared in 1949	21
4. Sassafras fine sandy loam in potatoes for over 35 years	1828
5. Sassafras fine sandy loam in lima beans for over 30 years	448
6. Lordstown silt loam in potatoes for ten years or more	1396
7. Ontario silt loam alternately in potatoes and oats for ten years	152
L.S.D. at the 5 per cent level	424
L.S.D. at the 1 per cent level	607

ination. Field 2, which has been planted to potatoes continuously for more than twenty years, did not have a significantly higher *Pratylenchus* count than the fields in which potatoes have never been grown. In the other two fields planted to potatoes continuously for many years, however, the *Pratylenchus* counts were significantly higher.

A much more extended survey would be needed to compare conclusively the effects of continuous cropping with potatoes and rotation on populations of plant parasitic nematodes. This survey does indicate a widespread occurrence of *Pratylenchus* species in New York State.

SUMMARY

A comparison was made of the kinds and numbers of nematodes present in several fields where potatoes had been grown continuously for many years, and other areas, some of which were of the same soil type, where potatoes had not been grown. Nematodes were removed from the soil by screening instead of by the use of the Baermann funnel because the Baermann funnel was found to be inefficient for the recovery of plant parasites. A more extended survey would be needed to determine conclusively the effects of continuous cropping with potatoes on populations of plant parasitic nematodes. The only plant parasitic nematodes present in large quantity in any of the fields surveyed were two undescribed species of *Pratylenchus*.

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THE RAPIDITY OF VINE-KILLING BY HERBICIDES IN RELATION TO INTERNAL TUBER DISCOLORATION IN POTATOES[1]

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In 1945 and 1946, ten herbicides were tested in the field to determine their effectiveness in killing potato vines prematurely. Three herbicides, Handy Killer (45.3 per cent sodium arsenite), Dowspray 66 Improved (10.7 per cent dinitro ortho secondary butyl phenol, 1.8 per cent Triton B 1956, and 87.5 per cent mineral oil), and Sinox General (75 per cent dinitro ortho secondary amyl phenol), were the most promising. These materials were used in field tests for the years 1947 to 1950 inclusive.

In these tests, particular attention was paid to the rapidity of killing and to the amount of internal discoloration in the tubers. For this reason, all materials were applied at the maximum concentrations recommended by the manufacturer.

METHODS AND MATERIALS

The experimental plots were each 60 ft. long and 12 ft. wide. The Green Mountain variety was used, and the plants were sprayed regularly throughout the growing season with Bordeaux 10-5-100 plus Deenate. The herbicides were applied at the rate of 200 gallons per acre with a power sprayer travelling both ways on each row.

The Handy Killer was prepared for application by mixing 80 fl. oz. plus 4 gal. fuel oil per 100 gal. of water; Sinox General, by mixing 40 fl. oz. plus 2 gal. fuel oil per 100 gal. water; and Dowspray 66 Improved, by mixing 2 gal. plus 2 lb. aluminum sulphate per 100 gal. of water.

The herbicides were applied during the first week of September in each year. A second and third series of plots were sprayed at intervals of 10 days to determine the effect of maturity of the vines on the rate of kill and on the incidence of tuber necrosis. For a period of one week after each application, notes were taken daily on the rate of killing. The general weather conditions for this period were recorded.

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Experimental Results

Table 1 gives a summary of the data relating to the experiments carried out during the four years 1947 to 1950, including the number of days required to kill the plants and the average rating for internal discoloration in the tubers.

For the years 1947 to 1950, Dowspray 66 proved to be a more effective herbicide for potato top killing than either Handy Killer or Sinox General. As the potato plants became more mature, the applications of Handy Killer and Sinox General were more effective, but the stage of maturity of the plants showed no definite effect on the rapidity with which they were killed by Dowspray 66 Improved. In general, the incidence of stem-end discoloration varied directly with the rate of killing, and there was a marked reduction in the amount of internal discoloration after the tubers were stored for four months.

Table 1.—*Number of days required to kill plants and average rating for internal discoloration in the tubers*[1]

Herbicide	Date of Application	No. of Days Required for Killing	Mean Temp. °F.	Ave. Sunshine Hrs.	Internal Discoloration[2] Rating	
					At Harvesting	After Storage
	Sept. 6	9	64.1	7.7	30.1	13.7
Killer	16	7	54.8	5.9	37.3	17.8
Handy	26	7	53.1	6.0	34.5	15.6
Mean		7.6	57.3	6.5	33.9	15.7
Dowspray	Sept. 6	5	64.1	7.7	68.6	32.0
66	16	5	54.8	5.9	51.6	19.1
Improved	26	5	53.1	6.0	44.5	16.8
Mean		5.0	57.3	6.5	54.9	22.6
	Sept. 6	7	64.1	7.7	37.2	14.5
Sinox	16	6	54.8	5.9	41.0	16.2
General	26	5	53.1	6.0	44.6	14.1
Mean		6.0	57.3	6.5	40.9	14.9
Check	Sept. 6	—	—	—	0.4	0.8
(no	16	—	—	—	4.7	1.4
herbicide)	26	—	—	—	15.6	1.0
					6.9	1.1

[1] Results recorded are averages for the four years, 1947 to 1950

[2] Internal discoloration rating=

$$\frac{(\text{Slight X } 1) + (\text{Moderate X } 2) + (\text{Severe X } 3) \text{ X } 100}{\text{No. of tubers}}$$

The plots were harvested approximately two weeks after the application of the herbicide and 200 tubers were picked at random from each plot. To reveal any internal discoloration, a thin slice was cut from the stem-end of each tuber. A second lot of 200 tubers was also picked at harvest and stored for 4 months, after which the tubers were cut and examined. A plot, not treated with a herbicide, was harvested along with each series of treated plots.

The cut tubers were assessed as having slight, moderate, or severe internal discoloration.

The rating of internal discoloration was calculated as follows:

$$\frac{(\text{Slight X } 1) + (\text{Moderate X } 2) + (\text{Severe X } 3) \times 100}{\text{Number of tubers examined}}$$

Summary

1. Dowspray 66 Improved killed potato vines more rapidly than either Handy Killer or Sinox General.

2. The stage of maturity did not influence the rate of kill with Dowspray 66, but more mature plants were killed more rapidly by Sinox General and Handy Killer.

3. The incidence of stem-end discoloration varied inversely with the number of days required to kill the plants.

4. There was a marked decrease in the amount of internal discoloration after four months in storage.

MECHANICAL SEPARATION OF POTATOES INTO SPECIFIC GRAVITY GROUPS SHOWS PROMISE FOR THE POTATO CHIP INDUSTRY*

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(Accepted for publication June 8, 1951)

In recent years much research has been done to determine the factors responsible for good cooking quality in potatoes and toward the development of methods, other than cooking, which are a reliable index of cooking quality.

Goldwaite (5) and Stevenson (14) have concluded that no two potato tubers are exactly alike in composition whether from the same variety or the same hill. Brewell (3) Clark (4) and Smith (11) have shown that even though wide differences in composition between individual tubers do occur that they can be graded into a more uniform cooking product by means of a specific gravity separation.

Brewell (3) and others have stated that present grade standards for potatoes give no indication as to how a potato will cook and Brewell (3) Smith (11) and Clark (4) have suggested brine solutions of varying densities for making selections for mealiness.

Because of the great variation in composition and cooking quality of individual tubers, and because it is possible to separate potatoes into cooking quality grades by means of specific gravity, a project to develop a machine capable of separating potatoes into specific gravity groups on a commercial scale was undertaken; and a machine capable of separating 12,000 pounds of potatoes per hour into two specific gravity groups, with an accuracy of from 3 to 4 per cent was developed (7).

Recently the importance of specific gravity to the potato chip industry was pointed out by the work of Whiteman (15) and Smith (12-13). They showed that for any given variety the high specific gravity tubers yield a higher per cent of chips, absorb less fat in frying, and the chips are a lighter more attractive color than those produced from the lower specific gravity tubers.

To test the effectiveness of the specific gravity grader in separating potatoes for the chip industry a study was undertaken in cooperation with the Greeley Spud Chip Company.

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* Grateful appreciation is extended to the Greeley Spud Chip Company for their cooperation.

*Sci. Serv. Paper No. 359.

METHODS

Twenty thousand pounds of potatoes, which had been conditioned for five weeks between 60 and 70 degrees Fahrenheit by the Greeley Spud Chip Company, were run through the specific gravity grader which was filled with water and sodium chloride to make a specific gravity of 1.0841, the estimated mean specific gravity of the potatoes. The temperature of the solution was 58 degrees Fahrenheit. The variety was Russet Rural and the tubers at the beginning were dry and unwashed. The tubers were run through the machine as rapidly as two men could remove them from the spray washer which was used to rinse the brine off the tubers. The actual time of separation was noted to determine the rate of separation.

During the period of separation, tubers were randomly taken from the low and high specific gravity groups and placed in their respective sacks until about a one hundred pound sample of each group was obtained.

The accuracy of separation was determined by placing the sample tubers from each group into a brine of specific gravity 1.0841. In the group which should have been 1.0841 or above, only the floaters were considered to be in error. In the group which should have been 1.0841 or below, only those tubers which sank to the bottom were considered in error. The specific gravity for the tubers in error was determined individually by Archimedes principle.

This was necessary since tubers of the same specific gravity as the solution could go into either group and not be classed as error.

The chips were fried in the automatic kettle of the Greeley Spud Chip Company. The temperature of the Veo Shortening (hydrogenated cottonseed oil) was maintained at approximately 350 degrees Fahrenheit at the point of introduction and 275 degrees Fahrenheit at the exit. Some fluctuation in temperature occurred particularly at the exit.

Each specific gravity group was run in duplicate. Tubers from the low specific gravity group were chipped the first day and the afternoon of the third day, whereas, tubers from the high specific gravity group were chipped the second day and the morning of the third day. The half-day tests served as a check on the full day tests.

During the chipping process, two-pound samples of chips were taken in such a manner that a total of eight pounds of chips was taken from each specific gravity group during the first two days and two pounds of chips from each group during the two check runs, making a total of ten pounds of chips for each specific gravity group.

The chip samples were taken to the laboratory in Fort Collins, and two approximately 18-gram samples from each two-pound sample were extracted with ethyl ether in a soxhlet-extractor to determine the ether

extractable fat. After extraction the tissue was dried in an oven at 68 degrees Centigrade. This temperature caused a slight browning of the tissue. To correct for any moisture or other loss which was not fat, unextracted samples were oven dried at 68 degrees Centigrade and a correction factor determined.

The mean specific gravity of the two groups, above and below 1.0841, was determined by cutting each large tuber through the center to overcome any effect of hollow heart because most of the hollow heart tubers went into the low specific gravity group even though they were of high specific gravity.

During the process of separation many decaying tubers floated to the low specific gravity side of the separator where they were picked out and discarded. Because of the tendency for tubers with decay spots to go to the low specific gravity side, it became necessary not only to weigh the potatoes into the abrasive peeler but also to weigh all the pared waste. This gave a better estimate of the actual pounds of potatoes chipped. The normal peeling loss went down the drain and was not accounted for but should have been about the same for both specific gravity groups.

Salable chips were determined by weighing the chips which the company retained for sale. This was done on the basis of how well the chips blended with each other in color and not on the basis of a color standard. The chips from the low specific gravity potatoes were generally darker in color and many of them would have been discarded because of their dark color had they occurred with the chips from the high specific gravity tubers.

Results

Table 1 shows that the potatoes were divided into two almost equal groups above and below specific gravity 1.0841 and that the potatoes were run through the machine at approximately 9200 pounds per hour. The mean specific gravity was 1.0916 for the group above 1.0841 and 1.0777 for the group below 1.0841.

Table 1.—*Efficiency of tuber separation in the specific gravity grader when the solution was set at 1.0841*

Total Pounds Separated	Time	Pounds above Sp. Gravity 1.0841	Pounds below Sp. Gravity 1.0841	Pounds Decayed Potatoes Discarded
20,000	130 Min.	9100	9400	1500

Table 2 shows the accuracy of separation. The solution in the separator was 1.0841 and there were no tubers that came out of the high specific gravity side of the machine which had a specific gravity less than 1.0841, thus giving a zero per cent error for the high gravity side of the machine. On the low gravity side of the machine, there were 10 pounds of potatoes out of 106.5 pounds which had a specific gravity equal to or greater than the 1.0841. This constituted an error of 9.4 per cent. However, tubers of the same specific gravity as the tank solution could have gone to either side and hardly be considered as error. The specific gravities of the 24 individual tubers constituting the error in table 2 are shown in table 3. The data show that 5 of the 24 tubers were the same specific gravity as the solution and that 10 were almost the same. If a small range ($\pm .0025$) were allowed the percentage error of separation would have been very small.

TABLE 2.—*Accuracy of separation as determined by a random sample of each specific gravity group*

Specific Gravity of Brine in Tank	Size of Sample in Pounds of Potatoes	Pounds Potatoes 1.0841 or Less	Pounds Potatoes 1.0841 or Above	Per cent Error
1.0841	106.5	96.5	10.0	9.4
	91.0	0.0	91.0	0.0

TABLE 3.—*Specific gravities of the 24 individual tubers classed as error in table 2*

1. 1.0879	7. 1.0866	13. 1.0854	19. 1.0847
2. 1.0877	8. 1.0866	14. 1.0853	20. 1.0842
3. 1.0874	9. 1.0863	15. 1.0852	21. 1.0841
4. 1.0872	10. 1.0856	16. 1.0852	22. 1.0841
5. 1.0869	11. 1.0855	17. 1.0851	23. 1.0841
6. 1.0867	12. 1.0854	18. 1.0851	24. 1.0841

The effect of specific gravity on the total yield of chips is shown in table 4. It can be seen that the mean specific gravity of the two groups differed by 0.0139 and that the mean yield of chips from the potatoes with the higher specific gravity was 2.91 per cent greater than for the group with the lower specific gravity. When the effect on salable chips, table 5, is used as the criterium for judging the yield it can be seen that the high specific gravity tubers produced more chips than the low specific gravity tubers by 3.46 per cent. Not only did the high specific gravity tubers produce more chips but the chips were lighter in color and had

the sorters thrown out only those chips which were as dark as those sorted out of the low specific gravity group, the difference in yield in favor of the high gravity group would have been even larger.

Table 6 shows the per cent of fat absorbed by the potato chips made from the high and low specific gravity potatoes. There was a mean difference of about 4.41 per cent more fat absorbed by the chips from the low specific gravity potatoes than was absorbed by the chips from the high specific gravity potatoes. This difference was compared by students test for "T" and found to be significant at odds greater than 19:1.

TABLE 4.—*The effect of specific gravity on the total yield of potato chips*

Mean Sp. Gravity	Sample	Potatoes* Pounds	Total Pounds Chips	Per cent Chips
1.0916	A	5041	1237	24.54
	B	2458	586	23.84
	Mean	3750	912	24.32
1.0777	A	4516	957	21.19
	B	2622	571	21.77
	Mean	3569	764	21.41
Diff. 0.0139	—	—	—	2.91

TABLE 5.—*The effect of specific gravity on the yield of salable potato chips*

Mean Sp. Gravity	Sample	Potatoes* Pounds	Total Pounds Salable Chips	Per cent Chips
1.0916	A	5041	1204	23.88
	B	2458	562	22.86
	Mean	3750	883	23.55
1.0777	A	4516	904	20.02
	B	2622	530	20.21
	Mean	3569	717	20.09
Diff. 0.0139	—	—	—	3.46

TABLE 6.—*The effect of specific gravity on the absorption of ether extractable fat by potato chips*

Specific Gravity	Mean Per cent Fat**
1.0916	37.05 ± .61
1.0777	32.64 ± .65
Diff. 0.0139	4.41

* Pounds of potatoes exclusive of decay and hand-pared waste.
**These values are relative, since ether extracts traces of substances, other than fat.

Discussion

The earliest figures available giving the amount of potatoes used by the potato chip industry go back to 1936 (2). At that time chippers were using 3 million bushels of potatoes annually. By 1945, 13,300,000 bushels of potatoes and by 1950 nearly 22,000,000 bushels of potatoes were processed into chips. This represents a little more than 328 million pounds of potato chips (1) (9) or an average annual *per capita* consumption of 2.2 pounds. This is an average daily consumption of 0.006 pounds (2.72 grams) of chips per day, which is less than two medium sized potato chips.

Chippers say their research disclosed that potatoes consumed in chip form do not compete with potatoes prepared in any other manner, and therefore they contributed a net increase of 22 million bushels to potato consumption in 1950 (1).

If these results are truly indicative of the situation it would not seem unreasonable to anticipate further large increases in the amount of potatoes going into the chip industry. In light of the low *per capita* consumption of chips and the fact that chips are tasty and ready to eat, the *per capita* consumption might be doubled. The results to date (12) (13) (15) would indicate that the increased yield of chips, the decreased fat absorption, and the more attractive color resulting from the use of high gravity potatoes, should more than offset the cost of separating potatoes into specific gravity groups and should result in either an increased profit to the chipper or a reduction in the cost of chips to the consumer.

If potatoes were separated as to their specific gravities and only the upper fraction used for chipping the mean specific gravity of the remaining fraction would be lower and the tubers would be less mealy but the uniformity of cooking would be improved. Mealiness and sloughing are correlated (10) and if the tubers which have a tendency to slough were separated out and sold to the chipping industry or as "baking" potatoes it is possible that both the culinary market and the potato chip market would benefit from it. (6) (7) (8).

Summary and Conclusions

Twenty thousand pounds of potatoes of the Russet Rural variety, which had been conditioned for five weeks between 60 and 70 degrees Fahrenheit were divided into two specific gravity groups, above and below specific gravity 1.0841. The separation was made at the rate of 9,200 pounds per hour by means of the specific gravity separator developed at the Colorado A & M College.

It was found that the high specific gravity potatoes (mean value 1.0916) averaged almost 3.5 per cent more salable chips than the low specific

gravity potatoes (mean value 1.0777) and that the color of the chips from the high gravity potatoes was lighter and preferable to that of the chips from the low gravity group. It was also found that chips made from the low specific gravity tubers absorbed an average of 4.4 per cent more fat than did chips made from the high specific gravity tubers.

The findings are in agreement with those of Whiteman and Wright, and Smith and indicate the desirability of high specific gravity Rural potatoes over low specific gravity potatoes for chipping.

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CANSO
A NEW POTATO VARIETY
HIGHLY RESISTANT TO LATE BLIGHT

Varietal Name—"Canso"

Originator—National Potato Breeding Project

Pedigree—*Solanum demissum* x Earlaine x Katahdin x Katahdin x Katahdin x Katahdin x Katahdin

History—This variety was developed at the Dominion Experimental Station, Fredericton, New Brunswick, under the National Potato Breeding Project. The primary objective in the development of this variety was late blight resistance.

Description—Plants medium in size, spreading; stems thick, slightly angled; nodes moderately swollen, green; internodes green; wings very prominent, heavily waved, green; stipules large, green; leaves medium length, midrib green, scantily pubescent; primary leaflets close, medium green, large size, definitely pointed; mean length 4.52 ± 0.37 inches, mean width 2.90 ± 0.37 inches, index 64.24 ± 2.03; secondary leaflets many in three positions, on midrib between pairs of primary leaflets, at junction of midrib and petioles of primary leaflets and on primary leaflet petioles; tertiary leaflets medium in number in three positions, on midrib between pairs of primary leaflets, at junction of midrib and petioles of primary leaflets and on primary leaflet petioles; inflorescence much branched; leafy bracts very small on about one-fifth of inflorescences; peduncles medium in length, intermittently winged; scantily pubescent; pedicels medium in length, green scantily pubescent.

Flowers—Calyx lobes medium in length, green, scantily pubescent; corolla large, color light lilac, anthers orange yellow; pollen poor; style slightly curved, stigma lobed, green.

Tubers—Shape short elliptical, medium thick, mean length 3.23 ± 0.15 inches, mean width 2.95 ± 0.13 inches, mean thickness 2.17 ± 0.11 inches; indexes, width to length 88.0 ± 5.66. Thickness to width 73.63 ± 5.07, thickness to length 67.45 ± 5.68; skin smooth, self colored, dark cream buff; eyes shallow same color as skin; eyebrows medium long, curved medium prominent; flesh white; maturity late.

Pathological Characteristics.

Viruses—Field immune to *Solanum* virus 4 (Virus B). Some field resistance to virus 1 (X virus). Only a minimum of X virus infection found in this seedling under field conditions.

Susceptible to *Solanum* Virus 2 (Y virus). Expresses this in the form of a severe mosaic and leaf drop streak. When X and Y viruses are combined, a rugose mosaic is produced. *Solanum* Virus 3 (Virus A) has been found in this seedling under field conditions and preliminary attempts to infect it artificially with this virus have been unsuccessful. Susceptible to leaf roll and bunch top viruses. Expresses symptoms very clearly.

Net Necrosis has not been found in these seedlings when infected with leaf roll virus.

Late Blight—This seedling possesses a high degree of resistance to late blight infection in the field and for this reason does not require fungicidal protection under average epidemic conditions.

Entomological—No evidence of resistance to insects. This seedling should be given insecticidal protection.

General—This seedling, under New Brunswick conditions, is fully equal to Katahdin in yielding ability. Its cooking quality is equal to Green Mountain.

KESWICK
A NEW POTATO VARIETY
HIGHLY RESISTANT TO LATE BLIGHT

Variety Name—"Keswick"

Originator—National Potato Breeding Project

Pedigree—*Solanum demissum* x Earlaine x Earlaine x Earlaine x Green Mountain

History—This variety was developed at the Dominion Experimental Station, Fredericton, New Brunswick, under the National Potato Breeding Project. The primary objective in the development of this variety was late blight resistance

Description—Plants large, erect; stems medium thick, slightly angled; nodes slightly swollen, green; internodes green; wings very slightly waved or straight, not prominent; stipules large, green glabrous; leaves moderately long, broad, midrib green, very scantily pubescent, winged, pairs of primary leaflets often not opposite; primary leaflets medium green, four pairs ,primary leaflets moderately open with little overlap; leaflet petioles green; mean length 4.12 ± 0.34 inches, mean width 2.50 ± 0.21, index 60.67 ± 4.45; secondary leaflets medium in number on midrib between pairs of primary leaflets; tertiary leaflets few to medium in number; in-

florescence medium branched; leafy bracts on approximately one-third of inflorescences; peduncles long, scantily pubescent; pedicels long, green, sparsely pubescent.

Flowers—Calyx lobe tips medium in length, green, scantily pubescent; corolla large, white, anthers orange yellow; pollen poor, style slightly curved, green stigma lobed.

Tubers—Shape elliptical to oblong; medium thick; mean length 3.42 ± 0.23 inches, mean width 2.97 ± 0.17 inches, mean thickness 2.23 ± 0.12; indexes, width to length 84.45 ± 7.91, thickness to width 74.13 ± 4.93, thickness to length 65.39 ± 6.03, skin smooth, self-colored, dark cream buff; eyes medium depth, same color as skin; eyebrows short to medium long, curved, medium prominent; flesh white; maturity medium late about midway between Irish Cobbler and Green Mountain.

Pathological Characteristics.

Viruses—Field immune to *Solanum* virus 4 (Virus B)

Susceptible to *Solanum* virus 1 (X virus). Shows a range of mosaic streaks ,depending upon the strain of the virus involved.

Susceptible to *Solanum* virus (Y virus) and expresses this virus in the form of a severe mosaic and leaf drop streak. When the X, and Y virus are combined, a rugose mosaic is produced. *Solanum* Virus 3 (Virus A) has not been found in this seedling under field conditions and preliminary attempts to infect it artificially with this virus have been unsuccessful.

Susceptible to leaf roll and bunch top viruses and expresses the symptoms of these two viruses very clearly.

Net necrosis has not been found in this seedling, when infected with the leaf roll virus.

Late Blight—This seedling possesses a high degree of resistance to late blight infection in the field and for this reason does not require fungicidal protection under average epidemic conditions.

Entomological—No evidence to resistance to insects. This seedling should be given insecticidal protection.

General—This seedling, under New Brunswick conditions, sizes early (same time as Irish Cobbler) and has equalled or surpassed other early varieties in yield when harvested early.

As a main crop variety, it has equalled Green Mountain in yield and cooking quality.

ANNUAL MEETING

of

THE POTATO ASSOCIATION OF AMERICA

December 11 - 12 - 13, 1951

Netherland-Plaza Hotel

Cincinnati, Ohio

Joint meetings will be held with The American Phytopathological Society, December 11, and with The American Association of Economic Entomology, December 13.

Abstracts of papers for all sessions must be in the hands of Ora Smith, Secretary, by October 8.

INDEX

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